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SPRAYING FOR THE CODLING MOTH

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Summary of Bulletin No. 114

1. Studies of apple blossoms in reference to time of opening, falling of petals and closing of calyxes, indicate that the first application of spraying material for the codling moth should be timed with reference to the young apples most advanced in development rather than to the average development of the entire setting of fruit or the belated specimens. Page 377

2. A test of different methods of applying spraying material indicated that the most effective distribution for the control of the first brood of the codling moth could be secured by the use of a Vermorel nozzle under high pressure, and applying a comparatively large amount of material. Page 382

3. Although one thorough application of spraying material at the proper time resulted in the control of a large percentage of the first brood of codling moth, somewhat better results may usually be expected from a greater number of applications. Page 385

4. In spraying for the second brood of codling moth in 1901, Paris green applied without lime caused excessive dropping of the fruit. Page 393

5. Many apples from the sprayed trees were slightly blemished by codling moth injuries which did not extend much below the surface. Fruit so injured kept well in cold storage. Page 397

6. Laboratory experiments showed conclusively that it is possible to kill at least part of the second brood larvæ of the codling moth by means of a poisonous spray applied even after the worms have entered the fruit. Page 400

7. In 1902 double strength home-made arsenate of lead gave better results against the second brood of codling moth than did Paris green used with lime. Page 403

8. In 1903 spraying for the second brood of the codling moth was much less effective than in 1902, owing probably to the fact that a much larger proportion of the larvæ entered the apples at the calyx. Paris green in combination with Bordeaux mixture gave better results than any of the other mixtures tested, though the double strength arsenate of lead proved nearly as effective. Page 408

9. Since it seemed probable that the failure to secure more marked results from the late spraying in 1903 was due, at least in part, to a lack of thoroughness in the early spraying, certain trees designed for the test of late spraying in 1904 were selected while in bloom, and thereafter sprayed under careful supervision. Heavy spraying early in the season gave decidedly better results than light spraying, in reference to the control of the second brood of the codling moth, even though both lots of trees were treated alike in the late sprayings. Page 412

10. Marked results were secured from all the late spraying in 1904. The double strength arsenate of lead gave the best results, though Paris green in combination with dilute Bordeaux mixture resulted in the saving of nearly as much fruit. Page 415

11. The average results for three years in the test of different spraying mixtures for the second brood of codling moth at Urbana, show a decided advantage in favor of late spraying as compared with no late spraying. Of the different mixtures used each of the three years, the double strength arsenate of lead gave the best average results, though for the two years in which Paris green was used in combination with standard Bordeaux mixture, this material gave fully as good average results as the arsenate of lead. Page 418

12. In 1906, tests in spraying for the second brood of codling moth were made in commercial orchards near Quincy and Griggsville. At both places the attack of the codling moth was so slight that even the check trees were not badly infested. Page 419

13. **Conclusions.** Page 427

SPRAYING FOR THE CODLING MOTH

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Spraying is recognized by Illinois apple growers as one of the essential operations in the production of high grade fruit. The accepted practice is to spray the orchard three times each year, using the combined mixture of Bordeaux and Paris green or some other arsenical poison. The usual recommendation is to make the first application just before the blossoms open, the second immediately after the petals fall, and the third a week or ten days later; and the best orchardists conform as closely to this outline as the weather conditions and the size of the orchard as compared with the working force will permit. The first application is directed primarily against the apple scab, but Paris green is included in the mixture for the purpose of killing any canker worms or other leaf-eating insects which may be present at that time. The second application is considered the most important one in reference to the codling moth, but is also important in reference to the scab. The third application likewise is directed against both these enemies. It is not a common practice in this State to spray for the codling moth alone, since the scab is very prevalent and can be combated at the same time. Hence, when spraying for the codling moth, the combined mixture of Bordeaux and Paris green is ordinarily used.

Time of Application

To be most effective against the codling moth, the application after the falling of the petals must be made while the calyxes of the young apples are still open, in order that the poison may become lodged in the calyx cavities and remain there in readiness for the young worms, which enter after the calyxes have closed, and feed for a few days within the calyx cavities before going deep into the flesh. It is ordinarily considered that from 75 to 85 percent of the larvæ entering the apples in spring gain entrance at the calyx end; and observations made at the Illinois Experiment Station in 1904 correspond very closely to these figures. Careful examinations were made of all the apples produced by three unsprayed Duchess trees including all windfalls which dropped after the "June drop," and all

the hand-picked fruit. Of these apples 1,065 had been injured by the first brood of the codling moth; and 77.74 percent of the injured apples had been attacked at the calyx. Six hundred and eighty-seven (687) windfalls from three unsprayed Whitney trees were also found to be injured by the first brood of the codling moth, and 79.91 percent of these had been entered at the calyx.

The fact that so large a proportion of the apples attacked by the codling moth are entered by way of the calyx emphasizes the importance of getting poison into the calyx cavities. If only a few trees are to be sprayed, there is usually little difficulty in making the application before the calyxes close, but if the orchard is large, or the working force and equipment inadequate, or the weather unfavorable, the completion of this application may be so delayed that some of the calyxes close before the poison is applied. It is important, therefore, to know how long the calyxes are likely to remain open, in order that sufficient help and apparatus may be employed to get over the orchard in ample time.

The length of time which elapses from the falling of the petals until the calyxes are fully closed varies for different varieties, and doubtless for the same variety in different seasons. It also varies for different clusters upon the same tree. In 1902, twenty clusters each of Whitney, Duchess, and Fameuse were marked with tags, and a record kept regarding the date of opening of each blossom, the falling of the petals and the closing of the calyxes. From this record, the number of days from the falling of the petals of the latest flower in each cluster to the complete closing of the first calyx in the cluster was determined. The shortest time was eight days and the longest seventeen days. The number of clusters for each number of days is indicated in the following table. Since not all the clusters set fruit, the total number is in each case less than twenty.

TABLE 1.—DAYS FROM FALLING OF PETALS TO CLOSING OF CALYXES IN INDIVIDUAL CLUSTERS

No. of days.	8	9	10	11	12	13	14	15	16	17	Total.
Whitney	2	4	1		4	3			1		15
Duchess	1	3		4	4	1	2		2		17
Fameuse				2	4	3	2	2		2	15

Observations were also made regarding the behavior of entire trees of nine different varieties. The figures given below indicate the number of days from the time when nearly all the petals had fallen—that is, the earliest date after blossoming that spraying might be commenced—until the first calyxes were fully closed.

Dominie	7	Grimes	10
Duchess	7	Ben Davis	11
Minkler	7	Fameuse	11
Whitney	8	Willow Twig	11
Winesap	9		

FIG. 1 THE CALYXES OF BLOSSOMS WHICH FAIL TO SET FRUIT SEEM NEVER TO CLOSE.

Nearly all the calyxes were closed on the respective trees in from four to five days after the closing of the first calyxes. This refers only to the calyxes of apples which were developing normally, and not to abortive specimens. The calyxes of blossoms which fail to set fruit seem never to close even though the rudimentary fruits may persist on the tree until after the other calyxes are closed. (See Fig. 1.)

Although several fruits may set in a cluster, many varieties normally mature only one fruit to each cluster. The others usually drop off while quite small. The fruit which usually has the best chance of surviving in the struggle among the individuals of a cluster is the one which develops from the blossom which opens first. This is usually the central blossom of the cluster and therefore has an advantage in location with reference to the food supply as well as an advantage in point of time.

Observations made on thirty clusters each of Whitney, Duchess, and Fameuse in the spring of 1902, when the season was normal and the conditions therefore favorable for the normal development of the flowers, show that the length of time which elapsed between the opening of the first and second blossoms in a cluster varied from one to three days, as is indicated in the table below.

TABLE 2.—DAYS FROM FIRST TO SECOND BLOSSOM IN SAME CLUSTER, 1902

Number of days.	1	2	3	Total.
Number of clusters, Whitney	19	5	6	30
" " " Duchess	3	26	1	30
" " " Fameuse	3	27		30

In 1903, fifteen clusters each of Whitney, Duchess, Ben Davis, and Grimes were marked for observation. The weather during the blossoming season was abnormal, there being two short periods of warm, bright weather, each followed by a cool period including a frost. In some of the clusters of Whitney and Duchess the first blossom opened at the very end of the first warm period, and the cool period immediately following retarded the development of the later flowers. None of the Grimes or Ben Davis opened during the first warm period. The first blossom in nearly every cluster of Grimes opened during the cool period, and the other flowers appeared at the beginning of the second warm period. None of the Ben Davis opened until the approach of the second warm period;

then they developed rapidly, so that in most cases the second blossom appeared within a day after the first. The following table shows the range of time for each variety and the number of clusters for each number of days.

TABLE 3.—DAYS FROM FIRST TO SECOND BLOSSOM IN SAME CLUSTER, 1903

Number of days.	Less than 1	1	2	3	4	Total.
Number of clusters, Whitney	2	4	3	3	2	14*
" " " Duchess	1	2	2	3	7	15
" " " Grimes			3	11	1	15
" " " Ben Davis	4	8	2	1		15

These observations show that the first blossom in a cluster may open from a few hours to three or four days ahead of any of the other blossoms. This relative forwardness, especially if marked, is usually maintained, so that the earliest blossom to open loses its petals first, and the calyx of the young apple developing from it closes before those of the other apples in the cluster. (See Fig. 2.)

If then, the earliest apple in each cluster—and the one of which the calyx closes first—is most likely to persist and mature, it is highly important that the spraying be timed with reference to the development of these most advanced specimens rather than to the average development of the entire setting of fruit, or the belated specimens.

Taking into consideration the variation in the different clusters on the same tree, and the fact that the calyx cavities can be more readily reached by the spray if the calyx is entirely open rather than partially closed, it is probable that the entire orchard should be sprayed within seven days from the time that most of the petals have fallen; and sufficient force and apparatus should be available to accomplish this end even if delays are encountered by reason of rainy weather or unavoidable accidents. It is true that for some varieties a longer time might be allowed, and that in a mixed orchard spraying could be commenced upon the earlier blossoming varieties before the others were ready, and thus the time for the entire orchard extended. Nevertheless, seven days is a safe basis

*One cluster was accidentally broken off before the second blossom opened.

upon which to calculate the amount of working force and apparatus needed.

METHOD OF APPLICATION

The method of applying the material may have as important a bearing upon the results as has the time of application. As already mentioned, the prime object of the application just after the falling of the petals is to place the poison within the calyx cavities of the young apples. If it were possible to place a quantity of poison

FIG. 2. THE CALYXES OF THE DIFFERENT APPLES IN THE SAME CLUSTER DO NOT CLOSE AT THE SAME TIME.

within the calyx cavity of each and every apple upon the tree, very few codling moth larvæ attempting to enter by way of the calyx would survive.

Although in commercial spraying it is practically impossible to attain this ideal, nevertheless some methods of application more closely approximate it than do others. In the spring of 1902 various tests were made to determine, if possible, the most efficient method of making the application. In all the tests the same pump was used, but it was worked at different pressures and with different nozzles, and different amounts of material were applied. A small portion of a tree was treated according to each method. As soon as the material was dry, notes were made regarding the amount and distribution of the spraying material visible about the calyxes. In all cases the combined mixture of Bordeaux and Paris green was used. The methods and results were as follows:

1. Double Vermorel nozzle with fine caps:
   a. High pressure;* spraying stopped before fine drops ran together. Only a small amount of material visible, many apples showing none whatever.
   b. High pressure; spraying continued until after drops had run together. Calyx cavities well filled with material.
   c. Low pressure; spraying stopped before drops ran together. Few calyxes hit; unsatisfactory.
   d. Low pressure; spraying continued for some time. Most of calyxes hit, but not properly covered.
2. Double Vermorel nozzle with coarse caps:
   a. High pressure; spraying stopped before drops ran together. Not much material visible.
   b. High pressure; spraying continued until after drops ran together. Most of calyx cavities filled with the material.
   c. Low pressure, using small amount of material. Not enough material, and distribution poor; unsatisfactory.
   d. Low pressure; spraying continued for some time. Distribution poor; unsatisfactory.
3. Bordeaux nozzle:
   a. High pressure; spraying stopped very soon. Not much material remained on the apples; distribution poor.
   b. High pressure; spraying continued for some time. Distribution poor.

The application which was most effective in filling the calyx cavities was that made in the form of a fine mist by means of a Vermorel nozzle under high pressure, and continued until the fine drops gathering in the calyx cavity ran together in the form of one or a few large drops. If sufficient pressure was kept up to make

*No pressure gauge was used, but the "high pressure" was probably about eighty pounds and the "low pressure" about thirty-five pounds.

the spray very fine, the coarse caps gave as good results as the fine caps, but this was difficult to accomplish with a hand pump. It seemed to make little difference whether the nozzle was held close to the apples or at a distance of two or three feet, since the spray leaves the nozzle in the form of a mist.

To further determine the distribution of spraying material applied in different ways, one hundred apples were picked at random, June 26, from each of two Whitney trees which had received one application of spraying material May 8. Both were sprayed with fine Vermorel nozzles, under high pressure, but one was sprayed until the drops of material ran together and the tree was dripping, while in the other case care was taken to stop spraying before the fine drops ran together. Each apple was cut open with a sharp knife and the calyx cavity carefully examined under a lens in search of particles of spraying material. It was observed that in some cases the material had penetrated into the calyx cavity beyond the point of attachment of the stamens, while in other cases it had not. The results of the examination were as follows:

TABLE 4.—DISTRIBUTION OF MATERIAL IN HEAVY AND LIGHT SPRAYING

	Heavy spray.	Light spray.
Specimens in which spraying material was visible in calyx cavity	86	20
Spraying material beyond stamens	67	8
Spraying material not beyond stamens	19	12
Specimens in which no spraying material was visible in calyx cavity	14	80
Number of specimens examined	100	100

That the method of application which left the spraying material deposited in the calyx cavities of the greater proportion of the apples was of greater efficiency than the other in controlling the codling moth is shown by the fact that ninety-seven of the hundred apples from the heavily sprayed tree were perfectly free from worm injury, and that only two worms had gained entrance by way of the calyx, while in the hundred apples from the lightly sprayed tree thirteen live worms were found, ten of which had entered through the calyx. One other worm had also entered by way of the calyx, but was not found. The test was repeated in 1904. Two Whitney trees were sprayed May 18; one heavily and the other lightly. One hundred apples picked at random from each were examined June 30. Nine of the hundred apples from the lightly sprayed tree showed evidences of codling moth attacks, though only two worms (one

living and one dead) were found in the calyx cavities. Refuse left by the other seven worms was found in the calyx cavities, but the worms themselves were lacking. It is probable that they died as a result of eating poison, but did not consume sufficiently large quantities to kill them immediately. Hence they were able to feed in the calyx cavity sufficiently long to leave considerable refuse*. On the other hand, in only one apple of the hundred from the heavily sprayed tree was there any evidence of the visit of a worm, and that worm did not proceed beyond the calyx cavity. If other worms attacked these apples, they were evidently killed before they did sufficient feeding to leave any traces of their work.

NUMBER OF APPLICATIONS

In the foregoing discussion regarding methods of application, reference has been had merely to the application immediately following the falling of the petals. Experiments were also undertaken to determine the relative efficiency of different numbers of applications made in different ways. In the spring of 1902, eleven Whitney trees which had already received the usual application of Bordeaux mixture and Paris green before blossoming, were selected for the purpose of making this test. The various trees were sprayed as indicated in the outline below. In all cases the combined mixture of Bordeaux and Paris green was used, and was applied by means of a barrel pump carrying one lead of hose, equipped with a bamboo extension rod and a double Vermorel nozzle fitted with fine caps. The "high pressure" used was about eighty pounds and the "low pressure" about thirty-five pounds. Under the high pressure the spray issued with considerable force and in the form of very fine mist-like drops, while under the low pressure the drops were much larger and the discharge weak. In making a "heavy application," the spraying was continued until the fine drops ran together and the material began to drip from the trees. In making a "light application," the spraying was stopped before the fine drops ran together. In both cases, the attempt was made to secure a uniform distribution of the material over the entire tree. In making a "careless application," low pressure and a small amount of material were

*It is true that there is no positive proof that these worms were killed by eating poison, for further observations made in this connection show that apples from unsprayed trees may sometimes contain similar evidences of worms having ceased operations early in their career.

TABLE 5.—EXAMINATION OF APPLES PICKED FROM VARIOUSLY TREATED TREES, JUNE 26, 1902

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Apples apparently not attacked	65	97	76	71	86	65	85	82	98	92	74
Attacked by codling moth at calyx:											
Live worm in calyx cavity	15	0	7	5	1	1	1	3	0	0	2
Dead worm in calyx cavity	0	0	0	0	0	0	0	0	0	1	0
Worm stopped in cavity, but not found	10	0	10	17	13	10	9	9	2	6	1
Worm not stopped in cavity											
Live worm in apple	4	0	3	1	0	13	0	2	0	0	8
Worm not found	4	2	1	3	0	7	0	3	0	0	11
Attacked by codling moth at other points:											
Worm reached interior of fruit	2	1	3	3	0	4	5	1	0	1	4
Total number of apples examined	100	100	100	100	100	100	100	100	100	100	100
Total number of live worms found which entered at calyx	19	0	10	6	1	14	1	5	0	0	10
Total number of apples injured by worms entering at calyx	23	2	11	9	1	21	1	8	0	0	21
Total number of apples apparently not injured	75	97	86	88	99	75	94	91	100	99	75

used; and no particular care was taken to reach all parts of the tree. The various treatments were as follows:

1. Check. Not sprayed (except before blossoming).
2. One heavy application; high pressure; May 8.
3. One light application; high pressure; May 8.
4. One careless application; low pressure; May 8.
5. Two heavy applications; high pressure; May 8, and 16.
6. Check. Not sprayed (except before blossoming).
7. Two light applications; high pressure; May 8, and 16.
8. Two careless applications; low pressure; May 8, and 16.
9. Three heavy applications; high pressure; May 8, 16, and 22.
10. Two heavy applications followed by two light applications; all under high pressure; May 8, 16, 23, and June 5.
11. Check. Not sprayed (except before blossoming).

June 26, one hundred apples were picked without selection from each of these trees, and carefully examined for codling moth injuries. Each apple was cut open so that its exact condition could be determined.* The results of this examination are given in Table 5.

Apples in which worms had been stopped in the calyx cavity were counted as not injured; those in which live worms were found in the calyx cavity, or in which worms had proceeded to the interior (whether found or not), were counted as injured. It is perfectly evident that the heavy spraying was more effective than the light or careless spraying, and there seemed to be a slight advantage in favor of more than one application. The heavy spraying seemed to be more effective than the other methods against the worms attacking the sides of the fruit as well as against those seeking entrance at the calyx.

July 2, the ground under the trees in this experiment was cleared of all windfalls, so that from that date an accurate record could be kept of all apples which fell. The fallen apples were gathered at frequent intervals from July 8 to 29 and the number from each tree recorded. Each apple was cut open and a record made regarding the number injured by the codling moth. On July 29, the apples remaining on the trees were harvested, sorted and counted. Those showing any indication of worm injury were cut open and critically examined. The second brood larvæ of the codling moth were entering the apples at this time, but their work could readily be distinguished from that of the first brood, and only the first brood injuries are to be considered in this connection. The results of these counts and examinations are given in Table 6. The windfalls include only those which dropped after July 2; the "total crop" in-

*The apples from trees 2 and 3 are those previously mentioned as having been examined to determine the distribution of the spraying material.

TABLE 6.—RECORD OF APPLES FROM WHITNEY TREES VARIOUSLY TREATED, 1902

	Check.	One heavy application.	One light application.	One careless application.	Two heavy applications.	Check.	Two light applications.	Two careless applications.	Three heavy applications.	Two heavy and two light applications.	Check.
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Number of windfalls	237	69	166	152	24	172	461	41	123	52	130
Number of hand-picked fruits	441	397	768	751	255	439	1526	374	1430	491	491
Total crop	678	466	934	903	279	611	1987	415	1553	543	621
Number of wormy windfalls	96	10	60	50	8	87	113	21	9	10	59
Number of worm-injured hand-picked fruits	66	9	69	38	15	84	67	28	27	4	78
Total number of wormy fruits	162	19	129	88	23	171	180	49	36	14	137
Percentage of total crop which fell before ripening	34.95	14.80	17.77	16.80	8.60	28.15	23.20	9.88	7.91	9.57	20.93
Percentage of windfalls which were wormy	40.50	14.49	36.14	32.89	33.33	50.58	24.51	51.22	7.31	19.23	45.38
Percentage of hand-picked apples which were wormy	14.98	2.26	8.98	5.06	5.88	19.13	4.39	7.48	1.88	0.81	15.88
Percentage of total crop injured by worms	23.89	4.07	13.81	9.74	8.24	27.98	9.05	11.80	2.31	2.57	22.06
Percentage of total crop which remained on trees uninjured by first brood codling moth	55.31	83.26	74.83	78.95	86.02	58.10	73.42	83.37	90.34	89.68	66.50

cludes the fruit picked from the trees July 29 and all windfalls which dropped after July 2. The term "wormy," or "worm-injured" means injured by a first brood larva of the codling moth.

By comparison of the figures for sprayed and unsprayed trees it can readily be seen that all the spraying was of benefit, even the careless applications resulting in the saving of considerable fruit. One heavy application gave much better results than one light application. The fact that the tree which received two heavy applications produced a greater percentage of wormy fruits than the one which received only one heavy application can be partially accounted for by the fact that this tree bore a much smaller number of fruits, for it is generally conceded that the smaller the crop the higher the percentage of wormy fruit is likely to be. It is also true that even when the number or fruits borne by each of several trees is nearly the same, one tree may be more severely attacked than another. This is illustrated by the differences in the percentages of wormy fruit from the three unsprayed trees, even though they were of the same variety in the same orchard and within a few rods of one another. If the percentage of the total crop which remained on the tree uninjured by the first brood of codling moth until picked be taken as the basis of comparison, the tree which received two heavy applications is slightly ahead of the one which received only one application. This is due to the fact that a smaller percentage of the fruits fell before they were ripe. The two treatments which stand out clearly ahead of the others in reducing the percentage of wormy fruits, and in maturing a higher percentage of the total crop are those given trees No. 9 and 10; namely: three heavy applications, and two heavy followed by two light applications.

This experiment regarding the different methods of spraying and number of applications was repeated in 1904. However, the spray pump was fitted with a pressure gauge so that the exact pressure could be known. The variety used this time was the Duchess. The trees were selected while in bloom, and had been sprayed once before blossoming. That application is not considered in this experiment, since it has no direct bearing upon the control of the codling moth. The first application after the petals had fallen was made May 21, the "high pressure" spraying upon this date being done with a gasoline power sprayer at a pressure of 125 pounds. The "low pressure" spraying was done with a hand pump at a pressure of 32½ to 37½ pounds, there being a variation of five pounds between the beginning and end of each stroke. The second application was made May 27, the high pressure spraying being done with

TABLE 7.—RECORD OF APPLES FROM DUCHESS TREES VARIOUSLY TREATED, 1904

	Check, unsprayed.	One heavy application.	One light application.	One careless application.	Two heavy applications.	Check, unsprayed.	Two light applications.	Two careless applications.	Three heavy applications.	Two heavy and two light applications.	Check, unsprayed.
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No.10	No.11
Number of windfalls	869	324	223	249	171	900	283	653	738	691	831
Number of hand-picked fruits:	675	626	418	807	234	1236	529	1496	1176	1075	1096
Total crop	1544	950	641	1056	405	2136	812	2149	1914	1766	1927
Number of wormy windfalls	265	66	49	42	27	391	74	154	56	102	363
Number of worm-injured hand-picked fruits	12	3	5	8	2	26	7	6	2	5	8
Total number of wormy fruits	277	69	54	50	29	417	81	160	58	107	371
Percentage of total crop which fell before ripening	56.28	34.10	34.79	23.57	42.22	42.13	34.85	30.38	38.55	39.12	43.12
Percentage of windfalls which were wormy	30.49	20.37	21.97	16.86	15.78	43.44	26.14	23.58	7.58	14.76	43.68
Percentage of hand-picked appleswhich were wormy	1.77	.47	1.19	.99	.85	2.10	1.32	.40	.17	.46	.73
Percentage of total crop injured by worms	17.94	7.26	8.42	4.73	7.16	19.52	9.97	7.44	3.03	6.06	19.25
Percentage of total crop which remained on trees uninjured by first brood of codling moth	42.94	65.57	64.43	75.56	57.28	56.65	64.28	69.33	61.33	60.58	56.46

a hand pump at a pressure of 80 to 100 pounds, for at this pressure there was a range of twenty pounds at every stroke. The low pressure used at this date was the same as for the first application. The third application was made June 6, with a gasoline power sprayer operated at a pressure of 125 pounds, and the fourth application, June 13, with a hand pump at a pressure of 80 to 100 pounds. All applications were made later than in 1902 on account of the season being later.

On June 27, all windfalls of every description were gathered from under each of the trees. All except the very small, shriveled specimens which had dropped very early, were counted and examined for codling moth injuries. From that date until July 28, the windfalls were gathered every few days, and a record kept regarding the number from each tree. These windfalls were cut open and examined for codling moth injuries, and a record kept regarding the condition of those from each tree.

On July 28, the apples remaining on the trees were picked, counted and carefully sorted. All fruits showing any indication of having been attacked by the codling moth were cut open to determine the exact nature and extent of the injury.

The results of the above mentioned counts and examinations are given in Table 7.

It will be seen that again all the methods of spraying employed resulted in a diminution of the percentage of the crop injured by the codling moth. However, the results appear less markedly in favor of the greater number of applications, or of one heavy as compared with one light application, than was the case in 1902. In fact, the tree which was given only one "careless" application had a smaller percentage of the total crop injured by worms than any other tree except the one receiving three heavy applications; and it also had the largest percentage of the total crop remaining on the tree uninjured until mature. It must be mentioned in this connection that this so-called "careless" application was probably made in a more thorough manner than many orchardists usually spray, and it is also possible that this tree may not have been so severely attacked by the codling moth as some others in the experiment.

Another difference in the results as compared with those of 1902 was that a much larger percentage of the crop dropped before ripening. This can be partially accounted for by the fact that windfalls dropping somewhat earlier were included in the count, and that the Duchess in this locality usually drops worse than the Whitney. However, the fact that the smallest percentage of fallen fruit was

from the tree receiving one "careless" application, and the next smallest percentage from the tree receiving two such applications challenges explanation. This may possibly have been due partly to individual differences in the respective trees or to local conditions affecting them. That such differences may occur is illustrated by the fact that one of the unsprayed trees lost a much larger proportion of its crop by dropping than did the other two. Yet it is probable that another factor had a more important influence. The foliage as well as the fruit dropped badly from the heavily sprayed trees, and much of the fruit was russeted by the spray. The lightly sprayed trees did not lose much foliage, but some of the fruit was russeted, though not so badly as that from the heavily sprayed trees. The carelessly sprayed trees showed very little russet on the fruit and practically no dropping of the foliage. There seemed to be a fairly constant relation between the amount of spraying material applied and the russeting of fruit and dropping of foliage. It is possible that if more lime had been used these injuries would not have followed. However, the whole question of russeting of fruit and injury to foliage is not thoroughly understood and is now the object of a special investigation by the department.

It seems then that the results of the work in 1904 do not warrant the drawing of definite conclusions regarding the best method and number of applications of spraying material for controlling the first brood of the codling moth. However, taking into consideration both seasons' work, it appears evident that the application made just after the falling of the petals should be sufficiently heavy and applied with sufficient force to place considerable spraying material within the calyx cavities of the young apples. It is probable that at least one other application should be made, and the results in 1902 show a marked advantage in favor of three or even four applications. Whether these subsequent applications should be heavy or light, does not appear from these investigations. It is thought by some that the later applications should be rather light with a view to securing a uniform distribution of the spraying material over the sides of the young apples, for the purpose of poisoning the worms seeking to enter at points other than the calyx.

SPRAYING FOR THE SECOND BROOD

While spraying for the first brood of the codling moth is a common practice among Illinois apple growers, very few have as yet attempted to control the second brood by spraying, and serious damage often results from the work of this late brood even in orchards which have been sprayed for the first brood. In central Illinois the first worms of the second brood enter the apples about July 20, and most of the codling moth injuries apparent upon winter apples at picking time are due to the work of this brood. A serious attack of the second brood is most disheartening to the grower, for the

FIG 3. APPLES RUINED BY SECOND BROOD LARVÆ OF THE CODLING MOTH.

injury is done after the apples have attained considerable size and even commenced to color, so that after the crop is apparently made, a large percentage of it may be ruined by the worms.

INVESTIGATIONS IN 1901

In the summer of 1901, tests were made by the Illinois Experiment Station to determine the feasibility of attempting to control the second brood of the codling moth by means of a poisonous spray. August 3, after the larvæ were entering the apples in large numbers, five trees, one each of Grimes, Ben Davis, Winesap, Fameuse, and Longfield, were sprayed with Paris green used at the rate of one-fourth pound to 50 gallons of water. Five other trees of the same varieties were selected and left unsprayed as checks. All these trees had received the three usual applications of Bordeaux mixture and Paris green in the spring. August 10, another application of Paris green was made to the trees sprayed August 3.

Beginning in the evening of August 17, there were frequent showers during four or five days. The sprayed trees seemed to be in normal condition August 19, but on August 23, it was discovered that the foliage of all the sprayed trees was badly injured and that the fruit was falling much worse than before the rains. The foliage injury was least on the Grimes. Although the falling of the fruit may have been due partly to a check in the normal activities of the tree caused by the injury to the foliage, it was evidently due primarily to injury to the stems of the apples themselves. The injury was often greatest at the point of attachment of the stem and apple —both apple and stem being injured. In some cases the skin of the entire cavity of the apple had turned brown and the flesh was beginning to decay; and in some cases the entire stem had turned brown and was apparently dead. Many apples apparently uninjured hung so loosely upon the tree that they would fall if jarred or slightly brushed against. This was especially noticeable in the case of the Winesap. The Grimes and the Fameuse were much less injured in the flesh about the stem than were the other varieties.

The increase in the amount of windfalls from the sprayed trees as compared with unsprayed trees immediately following the rains is shown by the following table giving a record of the amount (in pecks) of fallen apples gathered from under each tree on certain dates preceding and following the injury.

TABLE 8.—WINDFALLS BEFORE AND AFTER INJURY TO STEMS

Date.	Grimes.		Winesap.		Ben Davis.		Longfield.		Fameuse.	
	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.
Before injury: Aug. 16.....	.5	.2	.4	.3	.5	.1	4.	3.	3.	3.5
" " " 19.....	.5	1.25	.1	.1	.8	.2	7.	5.	4.	7.
After injury: " 21.....	3.3	2.5	9.3	.5	2.1	.4	9.	4.8	7.	6.2
" " " 26.....	3.3	1.6	6.8	.3	6.3	.3	4.9	2.5	4.3	2.5
" " " 28.....	2.1	1.5	2.2	.4	5.	.4	2.	1.2	2.5	1.6
" " " 31.....	2.1	2.7	1.5	.9	3.4	.6	2.4	1.5	2.5	2.2

Before the injury to the stems occurred nearly all the windfalls consisted of apples which had been injured by worms. After the injury to the stems, a large percentage of the apples which fell from the sprayed trees were free from insect attack. The windfalls of three varieties gathered on five different dates were examined, and the percentage of sound (*i. e.,* uninjured by worms) fruit determined. The percentages are given in the following table:

TABLE 9.—PERCENTAGES OF SOUND WINDFALLS BEFORE AND AFTER STEM INJURY

Date.	Grimes.		Winesap.		Ben Davis.		Average.	
	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.
August 16.....	1.69	0	23.07	7.89	1.78	0.		
" 19.....	0.0	0	6.66	0.0	0.0	0.		
Average before injury	.84	0	14.86	3.94	.89	0.	5.53	1.31
August 23.....	41.	0	92.	4.	24.	0.		
" 26.....	32.	0	92.	0.	52.	4.54		
" 31.....	18.	0	86.	0.	68.	1.96		
Average after injury..	30.33	0	90.	1.33	48.	2.16	56.11	1.16

In spite of this excessive dropping of the fruit from the sprayed trees for a few days following the rain, the total percentage of the crop on the trees August 15 which fell before the harvest averaged greater for the unsprayed than for the sprayed trees. The percentages for each variety are given in the following table:

TABLE 10.—PERCENTAGE OF CROP WHICH FELL BEFORE THE HARVEST

	Sprayed.	Check.
Grimes.....	62.6	92.5
Winesap.....	70.9	74.3
Ben Davis.....	70.3	63.5
Longfield.....	97.6	96.9
Fameuse.....	87.7	90.7
Average.....	77.82	83.58

This means that the spray saved more apples from insect injury than it caused to drop by reason of injury to the stems.

The fruit from the trees in this experiment was picked from September 23 to September 28. In all cases, both trees of the same variety were picked the same day. The fruit was carefully sorted and examined for codling moth injuries. Many of the fruits which had been attacked by second brood larvæ of the codling moth were only slightly injured, the worm having ceased operations and disappeared without going much below the surface of the fruit. Such injuries had usually partially healed over, and did not sufficiently blemish the fruit to render it unfit for market or even for storage. It would readily be classed as No. 2 under the most rigid grading.

Since nearly all the fruit had fallen from the Longfield trees before picking time, the hand-picked crop of this variety was not

TABLE 11.—HAND-PICKED APPLES FROM SPRAYED AND UNSPRAYED TREES, 1901

	Grimes.		Winesap.		Ben Davis.		Fameuse.	
	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.
Percentage injured by first brood only	4.83	8.33	1.63	2.64	3.44	5.00	5.45	2.58
Percentage attacked by second brood codling moth	37.14	55.21	39.99	50.14	55.40	68.72	41.11	33.74
Percentage in which worms stopped near surface	17.71	9.37	27.08	7.92	36.53	5.00	25.77	6.45
Percentage injured for storage by second brood	19.43	45.84	12.91	42.22	18.87	63.72	15.34	27.29
Percentage uninjured for storage by worms (both broods)	75.74	45.83	85.46	55.14	77.69	31.28	78.71	70.13
Percentage of the apples attacked by second brood, in which worms stopped near surface	47.68	16.98	67.71	15.79	65.93	7.27	62.69	19.11

If the results from the four varieties are averaged, the following percentages are obtained:

TABLE 12.—AVERAGE FOR THE FOUR VARIETIES

	Sprayed.	Check.	Gain due to spray.
Percentage attacked by second brood codling moth	43.41	51.95	8.54
Percentage in which worms stopped near surface	26.36	7.18	19.18
Percentage injured for storage by second brood	17.05	44.77	27.72
Percentage uninjured for storage by worms (both broods)	79.56	50.59	28.97
Percentage of the apples attacked by second brood, in which worms stopped near surface	61.00	14.79	46.21

examined for worm injuries. The results of the examination of the four other varieties, reduced to percentages, are given in Table 11.

Tables 11 and 12 show that with the exception of one variety (the Fameuse) a smaller percentage of the apples from the sprayed trees were visibly attacked by worms than from the unsprayed trees, and that the average percentage for the four varieties (including the Fameuse) was smaller for the sprayed than for the unsprayed trees. The tables further show that a very much larger percentage of the worms attacking the apples had stopped before going to the interior in the case of fruits from the sprayed trees.

STORAGE TEST OF APPLES ATTACKED BY CODLING MOTH

The statement has been made that fruits attacked by second brood larvæ of the codling moth in which the worms did not penetrate much beneath the surface were not rendered unfit for storage. Fruits in this condition from sprayed trees were placed in cold storage for the sake of comparing their keeping quality with that of unblemished specimens of the same varieties from the same trees. The number of specimens in each lot was as follows:

	Lot 1. Unblemished.	Lot 2. Worm-attacked.
Grimes	35	24
Fameuse	27	17
Winesap	21	24
Ben Davis	23	22

Examinations were made at intervals during the season, and the following notes were taken regarding the condition of the fruit.

November 19:—

Grimes: Both lots perfectly sound, but showing some slightly withered specimens.

Fameuse: Lot 1 (unblemished). Some specimens somewhat withered; one entirely rotten; two showing rotten specks where skin had been broken. (Only the entirely rotten specimen was removed.)

Lot 2 (worm-attacked). Some specimens somewhat withered. No rotten apples. Two specimens show rotten spots where skin had been broken. One of these has two rotten spots, one of which is at a worm injury. Balance keeping perfectly about worm injuries.

Winesap: Lot 1 (unblemished). In perfect condition.

Lot 2 (worm-attacked). Keeping perfectly except that a few specimens are slightly withered.

Ben Davis: Lot 1 (unblemished). In perfect condition.

Lot 2 (worm-attacked). Keeping perfectly except one specimen which is beginning to rot at the blossom end.

February 19:—

Grimes: Lot 1 (unblemished). No rotten apples, and none with rotten specks. Quite badly withered.

Lot 2 (worm-attacked). Five specimens specked with rot, one specimen one-fourth decayed, eighteen badly withered but without rot.

Fameuse: Lot 1 (unblemished). One specimen shows a small rotten speck. All other specimens are withered, but not rotting.

Lot 2 (worm-attacked). Four specimens about half rotten; all others badly withered, but not rotting.

Winesap: Lot 1 (unblemished). Perfectly sound. None withered.

Lot 2 (worm-attacked). No rot. A few specimens slightly withered.

Ben Davis: Lot 1 (unblemished). No rot. Keeping well.

Lot 2 (worm-attacked). No more rot than November 19. Keeping well.

March 18:—

Grimes: Lot 1 (unblemished). Two specimens breaking down, two badly spotted with rot, two slightly spotted, ten badly withered but not rotting, nineteen perfectly sound though part of them are somewhat withered.

Lot 2 (worm-attacked). Four specimens badly rotted, five specked with rot, seven badly withered but not rotting, eight sound (slightly more withered than in lot 1).

Fameuse: Lot 1 (unblemished). Two specimens badly decayed, five badly spotted with rot, three slightly spotted, six badly withered but not rotting, ten sound but slightly withered.

Lot 2 (worm-attacked). Three specimens badly decayed, three badly spotted with rot, three slightly spotted, eight sound but considerably withered (much more so than in lot 1).

Winesap: Lot 1 (unblemished). No signs of rot. Six specimens slightly withered, fifteen perfectly sound (not withered).

Lot 2 (worm-attacked). No signs of rot. Two specimens badly withered, seven slightly withered, fifteen perfectly sound (not withered).

Ben Davis: Lot 1 (unblemished). One specimen slightly spotted, three slightly withered, nineteen perfectly sound (not withered).

Lot 2 (worm-attacked). Two specimens badly spotted, four somewhat withered, sixteen perfectly sound (not withered).

At this date the Grimes and Fameuse were withdrawn from storage.

April 19:—

Winesap: Lot 1 (unblemished). No signs of rot. Some specimens somewhat withered.

Lot 2 (worm-attacked). No signs of rot. Many specimens still firm, but on the average slightly more withered than lot 1.

Ben Davis: Lot 1 (unblemished). One specimen slightly spotted, four somewhat withered, eighteen perfectly sound and firm.

Lot 2 (worm-attacked). Three specimens with rotten spots. In only one, however, does the rotten area surround the worm injury. One specimen scalded, four somewhat withered, fourteen perfectly sound and firm.

These notes show that apples attacked by the second brood of the codling moth, in which the worm stopped before going deeply into the fruit, kept in cold storage almost as well as fruits which were without blemish, the chief difference being that the blemished fruits became somewhat more withered than the unblemished specimens. When the fruits began to decay, the rot usually did not start from the point of worm injury, and was nearly as prevalent on unblemished as blemished specimens. The condition of the Winesap and Ben Davis at the end of the storage period indicates that there

need be no great fear of loss by reason of rot or poor keeping of apples injured in the manner specified, in the case of long keeping varieties.

FIG. 4. APPLES ATTACKED BY SECOND BROOD OF CODLING MOTH.

FIG. 5. THE SAME FRUITS AS IN FIG. 4, CUT OPEN TO SHOW EXTENT OF INJURY. THE WORM STOPPED CLOSE TO THE SURFACE IN THE FRUIT AT THE LEFT.

Tables 11 and 12 (p. 396) show that many apples were injured in the manner specified, and that the proportion was much greater from sprayed than unsprayed trees; that is, a much larger proportion of the apples showing evidences of insect attack were only slightly injured and not rendered unfit for storage in the case of sprayed than unsprayed trees. In the case of unsprayed trees it is evident that the worms which ceased activities and disappeared after entering the apple but before penetrating deeply into the flesh must have done so from natural causes, but the fact that the proportion of worms so doing was so much larger in the case of fruit from sprayed trees indicates that at least part of these worms must have been killed by the spray after they entered the fruit. It will be remembered that the late spraying was not commenced until after many worms had entered the fruit.

LABORATORY INVESTIGATIONS

Investigations were made in the laboratory to determine whether or not the worms could be killed by the spray in the manner above suggested. The examination of windfalls which had been entered by 457 larvæ of the second brood showed that 43.76 percent of these larvæ entered at the side of the apple, 33.48 percent at the calyx, and 22.75 percent close to the stem. Particular attention was given to studying the effect of a poisonous spray upon the larvæ entering the side of the apple, applied after they had entered.

After entering an apple, the worm feeds for a few days close to the surface, usually eating in a circle about the point of entrance, just beneath the skin, sometimes even eating holes through the skin. A deposit of excrement invariably covers the point of entrance and increases in size as the worm continues its work. When the apple is sprayed, a drop of the liquid usually lodges on or in the accumulation of excrement, since the particles of the latter present a rough and porous mass which is sure to absorb and hold some of the liquid. An examination of sprayed apples revealed the presence of numerous particles of Paris green on the skin of the apple close about the outer edge of the mass of excrement and also lodged among its particles.

Six apples were sprayed in the laboratory August 7, by means of an atomizer charged with Paris green used at the rate of one-half pound to 50 gallons of water. All these apples had been entered by worms. Five more apples were sprayed in like manner August 9. In this case the Paris green was used at the rate of one pound to 50

gallons. August 12, these apples were examined to determine the condition of the worms. The larvæ were carefully sought and removed under a dissecting microscope, and were then placed on a glass slide and examined under a compound microscope. If they showed no signs of life, they were designated "dead;" if they showed slight signs of activity, such as the moving of the jaws, but seemed weak and sick, they were designated "nearly dead;" if they wriggled vigorously, they were designated "healthy." In all cases, the "dead" and "nearly dead" worms were close to the surface of the fruit. In these examinations no note was taken as to whether the healthy worms had gone to the interior of the fruit or not. The condition of the worms was as follows:

Worms dead	4
Worms nearly dead	3
Worms healthy	9
Total	16

Since some of these worms had been in the apples several days and had probably gone to the interior of the fruit before the spray was applied, a fresh supply of apples was procured from the orchard August 12, and sprayed in the laboratory, with Paris green used at the rate of one pound to 50 gallons. The mixture was purposely made much stronger than it would be used in orchard operations. The apples were divided into three lots of seven each. In lot 1, the apples had been very recently entered by the worms; in lot 2, the worms had entered somewhat earlier, while in lot 3, they had entered still earlier, so that some of them may have gone to the interior before the spray was applied. These apples were carefully examined three days after the spray was applied. The condition of the worms was found to be as follows:

TABLE 13.—CONDITION OF WORMS IN SPRAYED APPLES

	Lot 1.	Lot 2.	Lot 3.	Total.
Dead	5	3	4	12
Nearly dead	0	1	0	1
Healthy (near surface)	1	1	1	3
Gone to interior	0	1	2	3
Not found	1	2	0	3
Total	7	8	7	22

In all cases the worms which had gone to the interior were apparently healthy. One of the dead worms in lot 3 had apparently been killed by a fungous disease rather than by the spray, so that

the total number of worms evidently killed by the spray would be eleven, or fifty percent of the worms attacking the apples. As might have been expected, a larger proportion of the worms succumbed in the case of apples sprayed very soon after the worms had entered.

In order to test further this matter and to make sure that it was the Paris green which caused the death of the worms, three lots of apples were again selected, and sprayed in the laboratory, and the same number in a similar condition in each case left unsprayed as checks. The relative ages of the worms in the various lots were the same as in the previous test. The examination made three days after the spraying was done showed the condition of the worms to be as follows:

TABLE 14 —CONDITION OF WORMS IN SPRAYED AND UNSPRAYED APPLES

	Lot 1.		Lot 2.		Lot 3.		Summary.	
	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.	Sprayed.	Check.
Dead	2	0	1	0	2	0	5	0
Nearly dead	0	0	1	0	2	0	3	0
Healthy (near surface)	1	1	1	0	2	0	4	1
Gone to interior	0	2	1	4	1	6	2	12
Killed by parasites	0	0	0	0	0	1	0	1
Total	3	3	4	4	7	7	14	14

Of the fourteen worms in the unsprayed apples, every one, except the one killed by parasites, was apparently healthy, while of the fourteen worms in the sprayed apples, only six were in a like condition; and there seems to be no question but that the Paris green was the cause of this difference.

The laboratory experiments, then, show conclusively that it is possible to kill at least a part of the second brood larvæ of the codling moth by means of a poisonous spray applied even after the worms have entered the fruit. However, the fruit in which a worm is killed near the surface will be slightly blemished, and although it will keep fairly well in cold storage, is not as high grade a product as is fruit without blemish. This indicates that although an apple crop may be saved from utter ruin by late spraying commenced after the second brood worms have begun to enter the apples, it would be much better to kill the worms, if possible, before they enter the fruit.

INVESTIGATIONS IN 1902

In 1902, the spraying was commenced before any worms of the second brood had entered the apples, with a view to reducing, if possible, the percentage of fruit slightly damaged by worms stopped near the surface. An attempt was also made to find a spraying mixture that would be effective against the worms and at the same time not cause excessive dropping of the fruit by reason of injury to the stems.

For the purpose of this experiment, ten trees, five each of Grimes and Ben Davis, were selected July 10, and sprayed on the same day with mixtures made according to the formulas indicated below, there being one tree of each variety under each of the different treatments. All these trees had received the three usual applications of Bordeaux and Paris green in the spring.

1. Paris green ¼ lb., lime about 2 lb., water 50 gal.
2. Paris green ½ lb., lime about 2 lb., water 50 gal.
3. Arsenate of lead: lead acetate 12½ oz., soda arsenate 5 oz., water 50 gal.
4. Double strength arsenate of lead: lead acetate 25 oz., soda arsenate 10 oz., water 50 gal.
5. Check—no late spraying.

For making the arsenate of lead, the lead acetate and soda arsenate were each dissolved separately in small quantities of cold water. The full amount of water for the complete mixture minus that used in dissolving the salts was measured out into a large vessel; then the solutions were added separately to this large volume of water, which was stirred thoroughly while they were being slowly poured in.

The Grimes were large trees over twenty years old, and the Ben Davis were small trees bearing their second crop. Twelve and one-half gallons of material were mixed in each case, but in most cases not quite all of the mixture was used in spraying the two trees.

The spray was applied by means of a hand pump worked at high pressure, and carrying only one lead of hose. A double Vermorel with fine caps was the nozzle employed. Particular care was taken to secure as nearly as possible a uniform distribution of material over all parts of all the apples, without allowing the fine drops to run together.

Additional applications of the same materials were made to the Grimes, July 25 and August 8, and to the Ben Davis July 25, August 8, 22, and September 5, so that altogether the Grimes received three applications for the second brood of codling moth, and the

TABLE 15.—EXAMINATION OF WINDFALLS, 1902

	Grimes.					Ben Davis.				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
Apples apparently injured by spray at stem	320	903	250	148	136	60	175	13	9	3
Sound	70	153	127	67	122	12	23	9	23	12
Sound except for spray injury at stem	224	707	109	45	23	40	122	9	2	6
Total sound	294	860	236	112	145	52	145	18	25	18
Injured by first brood codling moth	79	76	203	151	107	4	18	8	9	17
Injured by curculio	30	18	38	18	6	6	29	4	1	8
Injured by second brood codling moth:										
Entering at calyx	31	73	94	81	229	2	4	3	0	2
Entering at stem	4	9	42	26	100	0	1	0	0	3
Entering at hail scar	9	11	15	9	11	0	1	0	1	1
Entering at other points	11	19	49	40	170	1	3	1	5	15
Total injured by second brood codling moth	55	112	200	156	510	3	9	4	6	21
Otherwise injured	45	100	40	52	25	17	28	7	13	23
Total number of windfalls	503	1166	717	491	794	82	229	39	54	81
Percentage of windfalls which were sound	58.44	73.75	32.91	22.81	18.26	63.41	63.31	46.15	46.29	22.22
Percentage of windfalls injured by second brood codling moth	10.93	9.60	27.89	31.77	64.23	3.65	3.93	10.25	11.11	25.92
Percentage of windfalls apparently injured by spray at stem	63.61	77.44	34.86	30.14	17.12	73.17	76.44	33.33	16.66	3.70

Ben Davis five applications. All applications were made in the same manner and with equal thoroughness.

July 12, the ground under the trees was cleared of fallen apples of every description, so that a record could be kept of all apples falling after that date. These were picked up at intervals through the season, counted, and examined for insect injuries and also injuries to the stem apparently caused by the spray. Table 15 gives a summary of the records, and includes all apples which fell from the trees from July 12 until the hand-picked crop was harvested.

It will be seen that some of the windfalls from unsprayed trees are designated as "apparently injured by spray at stem." It is evident that such injury could not have been caused by the spray, since the trees were not sprayed. However, the stems were brown and dead, and the injury could not be distinguished from that to the stems of apples from the sprayed trees in the case of specimens in which the injury was confined to the stem itself. It is probable that some of the stem injury to apples from sprayed trees was not due to the spray. However, the fact that the percentage of stem-injured fruit was much greater for sprayed than unsprayed trees indicates that the spray must have caused much of the injury. Furthermore the high percentage of sound fruit among the windfalls from sprayed trees, especially those sprayed with Paris green, suggests that the spray must have caused the falling of much of this fruit.

That the Paris green, especially the stronger mixture, did cause an excessive dropping of the fruit is clearly shown by the following figures which represent in each case the percentage of the total number of apples on the tree July 12 which dropped before the hand-picked crop was harvested.

TABLE 16.—PERCENTAGE OF CROP WHICH FELL BEFORE MATURITY, 1902

Treatment.	Grimes.	Ben Davis.
1. Paris green, ¼ lb. to 50 gal., with lime	25.27	35.65
2. Paris green, ½ lb. to 50 gal., with lime	45.61	47.02
3. Arsenate of lead	17.36	13.26
4. Arsenate of lead, double strength	10.02	15.65
5. Check—no late spraying	35.02	21.03

The crop of Grimes was picked from the trees September 9 and 10, and the Ben Davis October 7. The apples were carefully sorted and counted. All specimens showing any indication of worm in-

TABLE 17.—EXAMINATION OF HAND-PICKED CROP FROM TREES SPRAYED FOR SECOND BROOD CODLING MOTH, 1902

	Grimes.					Ben Davis.				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
Total number of apples	1487	1390	3412	4407	1473	148	258	255	291	304
Visibly attacked by second brood codling moth	519	424	702	951	720	80	99	75	83	178
Injured for storage by second brood codling moth	260	179	316	366	483	3	8	15	10	115
Worm found in apple	71	55	114	112	207	0	0	3	1	21
Worm gone to interior but not found:										
Fruit badly damaged	40	33	84	90	131	0	3	6	6	67
Fruit not badly damaged	149	91	118	164	145	3	5	6	3	27
Uninjured for storage (worm stopped near surface)	259	245	386	585	237	77	91	60	73	63
Injured by first brood of codling moth	16	17	22	40	14	0	2	5	3	1
Injured by curculio	13	23	77	71	21	21	106	93	95	93
Injured by hail	382	378	1314	1351	224	9	16	23	36	8
Bird picked, or rotting	0	0	4	1	7	3	7	5	3	4
Sound	557	548	1293	1993	487	29	38	54	71	20

If these figures in reference to codling moth injuries to the hand-picked crop are reduced to percentages, the following results appear:

TABLE 18.—PERCENTAGE OF HAND-PICKED CROP INJURED BY CODLING MOTH, 1902

	Grimes.					Ben Davis.				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
Percentage visibly attacked by second brood codling moth	34.90	30.50	20.57	21.57	48.87	54.05	38.37	29.41	28.52	58.55
Percentage injured for storage by second brood codling moth	17.48	12.87	9.26	8.30	32.79	2.02	3.10	5.88	3.43	37.82
Percentage in which worms stopped near surface	17.42	17.62	11.31	13.27	16.09	52.02	35.27	23.53	25.08	20.72
Percentage injured by first brood only	1.07	1.22	.64	.90	.95	0.00	.77	1.96	1.03	.33
Percentage uninjured for storage by codling moth (both broods)	81.45	85.91	90.10	90.80	66.26	97.98	96.13	92.16	95.54	61.85
Percentage of the apples attacked by second brood, in which worms stopped near surface	49.90	57.78	54.98	61.51	32.91	96.25	91.91	80.00	87.95	35.39

jury were critically examined, and unless it was perfectly evident that the worm had been stopped close to the surface of the fruit so that the apple had not been injured for storage purposes, the specimen was cut open in order to determine the exact extent of the injury. The results of the examination of the entire hand-picked crop from each of the ten trees are given in Table 17. Injuries other than those caused by the second brood of the codling moth were recorded only in the case of specimens not visibly attacked by the second brood, and in no case was more than one injury recorded against the same specimen. All injuries are entered in the table in the order of their precedence, the most important or worst injuries, from the standpoint of this investigation, preceding those of less importance.

These figures show that in both varieties and under all treatments, the spraying caused a decrease in the percentage of fruits visibly attacked by the second brood of the codling moth. Although the percentage of apples slightly damaged by codling moth stopped near the surface was not as small as could have been desired, nevertheless the fact that in a much larger percentage of the apples visibly attacked the worms were stopped near the surface in the case of fruit from sprayed than unsprayed trees, indicates a marked benefit from spraying, and corroborates the results of the preceding year in so far as they apply to the feasibility of killing the worms after they have entered the fruit. The percentage of the entire hand-picked crop uninjured for storage by the codling moth, including the work of both broods, is much larger for the sprayed trees, under every treatment, than for the unsprayed trees.

The above considerations refer merely to the hand-picked fruit. Reference has already been made to the excessive dropping of fruit from certain of the sprayed trees. In order to make a fair comparison of the results of different treatments, it is essential that the windfalls as well as the hand-picked fruit be considered. So far as suitability for storage is concerned, all the windfalls may be put in one class, regardless of the cause or exact time of their falling. The net crop really consists of the hand-picked fruit suitable for storage. So far as this investigation is concerned, a true comparison of the different treatments can best be made by considering as suitable for storage all hand-picked specimens which have not been rendered unfit for storage by the work of the codling moth. If the percentage of the apples on the trees July 12 which remained uninjured for storage by the codling moth until gathered as hand-picked fruit be taken as the basis of comparison, the true relative merits of the

different treatments may readily be determined. Compared on this basis, the results appear as follows:

TABLE 19.—PERCENTAGE OF TOTAL CROP UNINJURED FOR STORAGE BY CODLING MOTH, 1902

Treatment.	Second brood.		Both broods.	
	Grimes.	Ben Davis.	Grimes.	Ben Davis.
1. Paris green, ¼ lb. to 50 gal., with lime	61.65	63.04	60.85	63.04
2. Paris green, ½ lb. to 50 gal., with lime	47.38	51.33	46.71	50.92
3. Arsenate of lead	74.98	81.63	74.44	79.93
4. Arsenate of lead, double strength	82 50	81.45	81.89	80.58
5. Check—no late spraying	43.67	49.09	43.05	48.83

It will be seen that the stronger mixture of Paris green gave but slightly better net results than no late spraying whatever. This was due to the excessive dropping of the immature fruit. The use of the weaker mixture of Paris green materially increased the percentage of fruit suitable for storage, but the arsenate of lead gave decidedly better results than the Paris green used at either strength. The double strength arsenate of lead seemed more effective on the Grimes than the usual strength, though on the Ben Davis, where five applications were made, the net results from the use of the two mixtures were practically identical.

INVESTIGATIONS IN 1903

The results of the work in 1902 plainly indicated that one-half pound of Paris green to 50 gallons of water, even when used with lime, was too strong a mixture to be applied to bearing apple trees in midsummer. This treatment was therefore not used in 1903. Since it is often advisable to spray with a fungicide late in the season, it was thought best to test the efficiency of Paris green used in combination with Bordeaux mixture as compared with Paris green and lime and with arsenate of lead. The following treatments for the second brood of codling moth were therefore tested in 1903.

1. Paris green ¼ lb., lime 4 lb., water 50 gal.
2. Paris green ¼ lb., lime 4 lb., copper sulphate 4 lb., water 50 gal.
3. Arsenate of lead.
4. Arsenate of lead, double strength.
5. Check—no late spraying.

The trees used for this experiment were the Grimes. All had received the three usual applications of Bordeaux mixture and Paris green in the spring. The method of application employed in the late

spraying was the same as in 1902. Applications were made July 17 and 27, August 10 and 24. No larvæ of the second brood of codling moth had been seen in the orchard up to the time of the first application.

All fallen apples under the trees were gathered the day the first application was made, and a record was kept of all apples falling after that date, except that the record for the check tree (No. 5) is incomplete on account of one of the workmen picking up the windfalls August 10, and mixing them with those from other trees in the orchard. This makes it impossible to determine the relative percentage of drop from the sprayed and unsprayed trees, but does not interfere with the comparison between the sprayed trees under different treatments. Table 20 gives a summary of the examination of windfalls.

TABLE 20.—EXAMINATION OF WINDFALLS, 1903

	No. 1	No. 2	No. 3	No. 4	No. 5
Apples apparently injured by spray at stem	152	300	255	609	289
Sound	61	105	96	147	33
Sound except for spray injury at stem	31	39	20	79	10
Total sound	92	144	116	226	33
Injured by first brood codling moth	139	392	311	499	330
Injured by curculio	33	63	50	49	68
Injured by second brood codling moth:					
Entering at calyx	85	234	258	336	350
Entering at stem	14	40	67	58	102
Entering at side	30	60	78	83	27
Total injured by second brood codling moth	129	334	403	477	479
Otherwise injured	7	18	18	37	43
Total number of windfalls	434	1009	945	1374	1067
Percentage of windfalls which were sound	21.19	14.27	12.27	16.44	3.09
Percentage of windfalls injured by second brood codling moth	29.72	33.10	42.64	34.71	44.89
Percentage of windfalls apparently injured by spray at stem	35.02	29.73	26.98	44.32	27.08

It will be seen that a much larger proportion of the windfalls were infested with codling moth than was the case in 1902, and that injuries caused by the first brood as well as the second were very much in evidence. This suggests that the early spraying, before the trees were selected for the experiment, was not as effective as it should have been. This spraying did not have special supervision, and no statement can be made regarding its thoroughness. The injury to the stems was, on the whole, less apparent than in 1902, though the double strength arsenate of lead seemed to result

in more injury than in the preceding year. The percentage of the crop on the trees July 17, which dropped before maturity, was in each case as follows:

TABLE 21.—PERCENTAGE OF CROP WHICH FELL BEFORE MATURITY, 1903

Treatment.	
1. Paris green, with lime	33.46
2. Paris green, with Bordeaux mixture	28.64
3. Arsenate of lead	35.83
4. Arsenate of lead, double strength	30.72

In spite of the greater proportion of stem-injured fruits among the windfalls from the trees sprayed with the double strength arsenate of lead, the proportion of the crop which dropped was less than for any of the other treatments except the Paris green with Bordeaux mixture. This treatment resulted in the smallest percentage of dropped fruit and showed also a comparatively low percentage of stem injury.

The apples from the trees in this experiment were picked September 8 and 9. The same method of examination of the hand-picked fruit was employed as in 1902, except that in addition, notes were made as to the points of entrance of the second brood larvæ. A summary of the results of the examination, corresponding to the items given for 1902, is given in Table 22.

TABLE 22 —EXAMINATION OF HAND-PICKED CROP FROM TREES SPRAYED FOR SECOND BROOD CODLING MOTH, 1903

	No. 1	No. 2	No. 3	No. 4	No. 5
Total number of apples	863	2513	1692	3098	2387
Visibly attacked by second brood codling moth:					
Injured for storage by second brood codling moth	317	819	828	1079	1007
Worm found in apple	163	331	373	517	392
Worm gone to interior but not found:					
Fruit badly damaged	105	300	280	363	487
Fruit not badly damaged	49	188	175	199	128
Uninjured for storage (worm stopped near surface)	80	112	129	222	102
Injured by first brood of codling moth	55	145	139	199	87
Injured by curculio	78	354	181	339	672
Bird-picked, rotting or otherwise injured	4	26	15	29	60
Sound	329	1057	400	1230	459

Reduced to percentages, the figures in reference to codling moth injuries appear as follows:

TABLE 23.—PERCENTAGE OF HAND-PICKED CROP INJURED BY CODLING MOTH, 1903

	No. 1	No. 2	No. 3	No. 4	No. 5
Percentage visibly attacked by second brood codling moth	46.00	37.04	56.56	41.99	46.42
Percentage injured for storage by second brood codling moth	36.73	32.59	48.93	34.82	42.15
Percentage in which worms stopped near surface	9.27	4.45	7.63	7.17	4.27
Percentage injured by first brood only	6.37	5.77	8.21	6.42	3.64
Percentage uninjured for storage by codling moth (both broods)	56.90	61.64	42.86	58.76	54.21
Percentage of the apples attacked by second brood, in which worms stopped near surface	20.15	12.03	13.48	17.06	9.19

These figures show that the spraying was much less effective than in 1902. Mention has already been made of the fact that the first brood of codling moth was not controlled by the early spraying This would naturally result in a severe attack of the second brood. Furthermore, if worms of the first brood, which normally enter the apples mainly by way of the calyx, were able to gain entrance without being poisoned, it is evident that worms of the second brood which sought entrance at the calyx would be safe from injury so far as any poison remaining from the early applications was concerned. In 1903, a much larger proportion of the second brood entered by way of the calyx than in 1902. If all the windfalls injured by second brood codling moth from the Grimes trees receiving no late spraying are considered, the percentages injured by attack at the different points, for the two years, were as follows:

Year.	At calyx.	At stem.	At side.
1902	44.90	19.60	35.49
1903	73.07	21.29	5.63

The fact that a very large proportion of the injuries due to the second brood of codling moth were caused by worms entering at the calyx is further illustrated by the records regarding the examination of the hand-picked fruit. Of the fruits injured for storage by the second brood of the codling moth, the following percentages were attacked at the calyx end:

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
54.25	65.44	75.24	62.92	72.49

Under these conditions it is not surprising that the late spraying was less effective than in 1902.

The percentage of the crop on the trees July 17, which remained uninjured for storage by the codling moth was as follows:

TABLE 24.—PERCENTAGE OF TOTAL CROP UNINJURED FOR STORAGE BY CODLING MOTH, 1903

Treatment.	Second brood.	Both broods.
1. Paris green, ¼ lb. to 50 gal., with lime	42.09	37.86
2. Paris green, ¼ lb. to 50 gal., with Bordeaux	48.09	43.98
3. Arsenate of lead	32.76	27.49
4. Arsenate of lead, double strength	45.14	40.69

These figures show that the best net results were secured from the use of Paris green in combination with Bordeaux mixture, though the double strength arsenate of lead proved nearly as effective.

INVESTIGATIONS IN 1904

Since it seemed probable that the failure to secure more marked results from the late spraying in 1903, was due, at least in part, to a lack of thoroughness in the early spraying, the trees designed for the work in 1904 were selected while in bloom, and thereafter sprayed under careful supervision. The trees were comparatively young Winesaps, and had been sprayed once with Bordeaux mixture and Paris green before the blossoms opened. After the petals had fallen, the two usual applications of Bordeaux mixture and Paris green were made. However, a difference was made in the amount of material used and the method of application for different trees. Seven trees were given a light application, the spraying being stopped before the fine drops ran together; and seven others were sprayed very heavily. The plan for the late spraying was to use one tree in each of these lots for each of several different treatments, including those employed the preceding year. However, the trees set so little fruit that it seemed best to treat them all alike in reference to the late spraying, in order to have sufficient fruit under each treatment to furnish a fair test regarding the influence of the method of the early applications upon the control of the second brood of the codling moth. The fourteen trees were therefore sprayed with Paris green and dilute Bordeaux mixture July 20 and 30, and August 10 and 26. The formula used in making the mixture was ¼ pound Paris green, 4 pounds lime, 2 pounds copper sulphate, 50 gallons water. The method of application was the same as in 1902 and 1903. The ground was cleared of windfalls July 19, and thereafter a record kept of all the apples which fell, the product of the seven trees under each treatment being considered as one lot.

There appeared to be little injury to the stems, and no record regarding that point was kept. The fallen fruit was carefully examined for worm injuries, and records kept regarding the point of entrance of the first brood as well as the second. A summary of the results is given in Table 25.

TABLE 25.—EXAMINATION OF WINESAP WINDFALLS, 1904

	Early applications.	
	Light.	Heavy.
Sound	243	584
Injured by first brood codling moth:		
Entering at calyx	92	52
Entering at stem	5	2
Entering at side	24	32
Total injured by first brood codling moth	121	86
Injured by curculio	15	23
Injured by second brood codling moth:		
Entering at calyx	85	62
Entering at stem	15	22
Entering at side	118	192
Total injured by second brood codling moth	218	276
Otherwise injured	26	60
Total number of windfalls	623	1029
Percentage of windfalls which were sound	39.00	56.75
Percentage of windfalls injured by first brood codling moth	19.42	8.35
Percentage of the windfalls injured by first brood codling moth in which the worm entered at the calyx	76.03	60.46
Percentage of windfalls injured by second brood codling moth	34.99	26.82
Percentage of the windfalls injured by second brood codling moth in which the worm entered at the calyx	38.99	22.46

The windfalls from the trees receiving the heavy early applications showed less worm injury from the first brood and also from the second, and there was, in the case of both broods, a smaller percentage of injury due to worms entering at the calyx.

The percentage of the total crop on the trees July 19, which fell before October 15, when the hand-picked fruit was gathered, was for the trees receiving the light early applications 45.77 percent, and for those receiving the heavy early applications 27.86 percent. This shows a decided advantage in favor of the heavy early spraying.

The hand-picked apples were carefully sorted and examined for codling moth injuries, and a complete record made as to the number of worms entering at the various points and the extent of injury in each case. The results of this examination are given in Table 26.

TABLE 26.—EXAMINATION OF HAND-PICKED CROP FROM WINESAP TREES SPRAYED FOR CODLING MOTH, 1904

	Early applications.	
	Light.	Heavy.
Total number of apples	738	2664
Visibly attacked by second brood codling moth at calyx:		
Injured for storage	20	18
Worm found in apple	14	7
Worm gone to interior but not found:		
Fruit badly damaged	0	3
Fruit not badly damaged	6	8
Uninjured for storage (worm stopped near surface)	72	82
Visibly attacked by second brood codling moth at stem:		
Injured for storage	1	5
Worm found in apple	0	2
Worm gone to interior but not found:		
Fruit badly damaged	0	0
Fruit not badly damaged	1	3
Uninjured for storage (worm stopped near surface)	0	2
Visibly attacked by second brood codling moth at side:		
Injured for storage	66	107
Worm found in apple	6	18
Worm gone to interior but not found:		
Fruit badly damaged	8	19
Fruit not badly damaged	52	70
Uninjured for storage (worm stopped near surface)	32	54
Injured by first brood codling moth	11	9
Entering at calyx	10	3
Entering at stem	0	0
Entering at side	1	6
Injured by curculio	2	3
Sound	534	2384

If these items are summarized to correspond with the tables given for preceding years, the figures appear as follows:

TABLE 27.—SUMMARY OF EXAMINATION OF HAND-PICKED FRUIT FROM WINESAP TREES, 1904

	Early Applications.	
	Light.	Heavy.
Total number of apples	738	2664
Visibly attacked by second brood codling moth:		
Injured for storage by second brood codling moth	87	130
Worm found in apple	20	27
Worm gone to interior but not found:		
Fruit badly damaged	8	22
Fruit not badly damaged	59	81
Uninjured for storage (worm stopped near surface)	104	138
Injured by first brood codling moth	11	9
Injured by curculio	2	3
Sound	534	2384

TABLE 28.—PERCENTAGE OF HAND-PICKED WINESAPS INJURED BY CODLING MOTH, 1904

	Early Applications.	
	Light.	Heavy.
Percentage visibly attacked by second brood codling moth	25.88	10.06
Percentage injured for storage by second brood codling moth	11.78	4.87
Percentage in which worms stopped near surface	14.09	5.18
Percentage injured by first brood only	1.49	.33
Percentage uninjured for storage by codling moth (both broods)	86.73	94.80
Percentage of the apples attacked by second brood, in which worms stopped near surface	54.45	51.49
Percentage of the apples injured for storage by second brood codling moth, which were entered at calyx	22.98	13.84

It will be seen that so far as the hand-picked fruit is concerned, the trees which received the heavy early applications showed much less injury from the second brood of the codling moth than did those receiving the light early applications. Applying the final test, the percentage of the entire crop on the trees July 19, which remained until the harvest as specimens uninjured for storage by the codling moth, the following figures are secured:

TABLE 29.—PERCENTAGE OF TOTAL CROP OF WINESAPS UNINJURED FOR STORAGE BY CODLING MOTH, 1904

	Second brood.	Both broods.
Light early applications	47.83	47.02
Heavy early applications	68.61	68.37

Viewed from every standpoint, the heavy spraying early in the season gave decidedly better results than the light spraying, in reference to the control of the second brood of the codling moth, even though all trees were treated alike in the late sprayings.

After it was decided not to use the Winesap trees for testing different materials applied late in the season, six Ben Davis trees that were well loaded with fruit were selected for this purpose. These trees had been sprayed twice after the petals had fallen, but the first application was made rather late, so that it is probable that many worms of the first brood had escaped destruction and that many apples were left unprotected against worms of the second brood attacking the fruit at the calyx. The usual mixture of Bor-

deaux and Paris green had been used in the early spraying. For the second brood of the codling moth, these trees were sprayed four times, the dates being the same as in the case of the Winesap. The treatments given and the percentages of the fruit which fell before maturity were as follows:

TABLE 30.—PERCENTAGE OF CROP WHICH FELL BEFORE MATURITY, BEN DAVIS, 1904

Treatment.	
1. Paris Green, ¼ lb. to 50 gal., with lime	25.49
2. Paris Green, ¼ lb. to 50 gal., with Bordeaux	20.47
3. Arsenate of lead	23.63
4. Arsenate of lead, double strength	19.30
5. Check—no late spraying	31.69
6. Paris green, ¼ lb. to 50 gal., with dilute Bordeaux	17.42

The examination of the windfalls revealed injuries as noted in the following table:

TABLE 31.—EXAMINATION OF BEN DAVIS WINDFALLS, 1904

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Sound	350	240	308	259	91	183
Injured by first brood codling moth:						
Entering at calyx	262	156	170	127	104	74
Entering at stem	3	9	9	6	7	5
Entering at side	57	58	64	31	29	38
Total injured by first brood codling moth	322	223	243	164	140	117
Injured by curculio	26	11	14	25	8	13
Injured by second brood codling moth						
Entering at calyx	311	192	241	160	244	149
Entering at stem	32	33	48	37	101	18
Entering at side	153	87	135	88	177	64
Total injured by second brood codling moth	496	312	424	285	522	231
Otherwise injured	20	17	5	27	11	12
Total number of windfalls	1214	803	994	760	772	556
Percentage of windfalls which were sound	28.83	29.88	30.98	34.07	11.78	32.91
Percentage of windfalls injured by first brood codling moth	26.52	27.77	24.44	21.57	18.13	21.04
Percentage of windfalls injured by second brood codling moth	40.85	38.85	42.65	37.50	67.61	41.54

These figures show that a much larger percentage of the windfalls from the tree receiving no late spraying were injured by the

second brood codling moth than of those from any of the sprayed trees. The examination of the windfalls from the tree receiving no late spraying shows that of the apples injured by the second brood codling moth, 47.65 percent were entered at the calyx, 17.77 percent near the stem, and 34.57 percent at the side.

The hand-picked crop of Ben Davis was gathered October 1. The apples were carefully sorted on the basis of codling moth injuries though no record was made as to whether the injuries were caused by worms of the first or the second brood. The apples designated as "worm injured" included all specimens attacked by the codling moth (of either brood), except those in which the worms had stopped close to the surface without noticeably disfiguring the fruit. Specimens in which the worms had not penetrated much beneath the surface, but which were at all badly disfigured, even though the injury was healed over, and specimens showing fresh worm attacks, indicating the possible presence of the live worm even though close to the surface, were considered as worm-injured. None of the specimens were cut open to determine the exact extent of the injury, but all were very carefully scrutinized during the sorting. The results of this grading were as follows:

TABLE 32.—EXAMINATION OF HAND-PICKED BEN DAVIS SPRAYED FOR CODLING MOTH, 1904

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Total number of apples	3548	3119	3213	3177	1664	2634
Injured for storage by codling moth	1893	1095	1302	1010	1146	931
Percentage of hand-picked crop injured for storage by codling moth (both broods)	53.35	35.10	40.52	31 79	68.87	35.34
Percentage uninjured for storage	46.65	64.90	59.48	68.21	31.13	64.66

The percentage of hand-picked fruit injured for storage by the codling moth was much greater in the case of the tree which received no late spraying than for any of the sprayed trees. The Paris green gave better results when used in combination with Bordeaux mixture, either standard or dilute, than when used with lime. The double strength arsenate of lead gave considerably better results than the ordinary strength.

The net results from each treatment (*i. e.*, the percentage of the crop on the trees July 19 which remained to be hand-picked as fruit

uninjured for storage by the codling moth of either brood) were as follows:

TABLE 33.—PERCENTAGE OF TOTAL CROP UNINJURED FOR STORAGE BY CODLING MOTH, BEN DAVIS, 1904

Treatment.	Both broods.
1. Paris green, ¼ lb. to 50 gal., with lime	34.75
2. Paris green, ¼ lb. to 50 gal., with Bordeaux	51.60
3. Arsenate of lead	45.42
4. Arsenate of lead, double strength	55.04
5. Check—no late spraying	21.26
6. Paris green, ¼ lb. to 50 gal., with dilute Bordeaux	53.38

Marked results were secured from the spraying under every treatment. The double strength arsenate of lead gave the best results, though the Paris green in combination with dilute Bordeaux resulted in the saving of nearly as much fruit. Owing to the fact that a somewhat smaller percentage of the crop fell before maturity, the tree sprayed with Paris green and dilute Bordeaux gave a slightly higher percentage of fruit suitable for storage than the tree sprayed with Paris green and standard Bordeaux. Both trees yielded a much larger percentage of storage fruit than the tree sprayed with Paris green and lime.

SUMMARY OF RESULTS FOR THREE YEARS

In order to present in condensed form the results of the experiments in late spraying for the control of the codling moth in 1902, 1903 and 1904, the following tables (34, 35 and 36) are introduced. The percentages given for 1902 were obtained by averaging the percentages for the two varieties.

TABLE 34.—PERCENTAGE OF CROP WHICH FELL BEFORE MATURITY

Treatment.	1902.	1903.	1904.	Ave.
1. Paris green, ¼ lb. to 50 gal., with lime	30.46	33.46	25.49	29.80
2a. Paris green, ½ lb. to 50 gal., with lime	46.31	....	....	....
2b. Paris green, with Bordeaux mixture	....	28.64	20.47	....
3. Arsenate of lead	15.31	35.83	23.63	24.92
4. Arsenate of lead, double strength	12.83	30.72	19.30	20.95
5. Check—no late spraying	28.02	....	31.69	....
6. Paris green, with dilute Bordeaux	....	....	17.42	....

TABLE 35.—PERCENTAGE OF HAND-PICKED CROP INJURED FOR STORAGE BY THE CODLING MOTH (BOTH BROODS)

Treatment.	1902.	1903.	1904.	Ave.
1. Paris green, ¼ lb. to 50 gal., with lime.....	10.28	21.55	53.35	28.39
2a. Paris green, ½ lb. to 50 gal., with lime.....	8.98	....	....	....
2b. Paris green, with Bordeaux mixture.....	....	19.18	35.10	....
3. Arsenate of lead.....	8.87	28.57	44.52	27.32
4. Arsenate of lead, double strength.....	6.83	20.62	31.79	19.74
5. Check—no late spraying.....	35.94	22.89	68.87	42.56
6. Paris green, with dilute Bordeaux.....	....	....	35.34	....

TABLE 36.—PERCENTAGE OF TOTAL CROP UNINJURED FOR STORAGE BY CODLING MOTH (BOTH BROODS)

Treatment.	1902.	1903.	1904.	Ave.
1. Paris green, ¼ lb. to 50 gal., with lime.....	61.94	37.86	34.75	44.85
2a. Paris green, ½ lb. to 50 gal., with lime.....	46.86	....	....	....
2b. Paris green, with Bordeaux mixture.....	....	43.98	51.60	....
3. Arsenate of lead.....	77.18	27.49	45.42	50 03
4. Arsenate of lead, double strength.....	81.23	40.69	55.04	58.98
5. Check—no late spraying.....	45.94	....	21.26	....
6. Paris green, with dilute Bordeaux.....	....	....	53.38	....

It will be seen that in two years out of the three, the benefits derived from the late spraying were very marked, except in the case of too strong a mixture of Paris green which caused excessive dropping of the immature fruit. The average results for the three years also show a decided advantage in favor of the spraying. Of the different spraying mixtures used each of the three years, the double strength arsenate of lead gave the best average results, though for the two years in which Paris green was used in combination with standard Bordeaux mixture, this material gave fully as good average results as the arsenate of lead. Paris green was used in combination with dilute Bordeaux mixture only one year. The net results were slightly superior to those obtained by the use of Paris green with standard Bordeaux, though this difference was probably due to a slight variation in the severity of the attack upon the different trees rather than to a difference in the real efficiency of the two mixtures.

INVESTIGATIONS IN 1906.

The investigations in reference to spraying for the second brood of the codling moth in 1901, 1902, 1903 and 1904 were conducted in the University orchard at Urbana, where the codling moth was

TABLE 37.—RECORD OF FRUIT FROM TREES SPRAYED FOR SECOND BROOD CODLING MOTH, QUINCY, 1906

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Number of windfalls	976	1127	965	942	812	1119	1680	1728	1249	1213	721	1147
Number of hand-picked fruits	5715	5706	7017	5812	4860	6237	7245	6926	6604	5872	6605	6977
Total crop.	6691	6833	7982	6754	5672	7356	8925	8654	7853	7085	7326	8124
Percentage windfalls	14.59	16.49	12.09	13.95	14.32	15.21	18.82	19.97	15.92	17.12	9.84	14.12
No. of windfalls injured by codling moth	68	120	83	207	110	63	222	171	115	170	66	207
No. of picked fruits injured by codling moth	79	148	123	372	180	68	245	174	91	203	154	339
Percentage of windfalls injured.	6.96	10.64	8.60	21.97	13.54	5.63	13.21	9.89	9.20	14.01	9.15	18.04
Percentage of picked fruit injured	1.38	2.59	1.75	6.40	3.70	1.09	3.38	2.51	1.38	3.46	2.33	4.86
Percentage of total crop injured	2.20	3.92	2.58	8.57	5.11	1.78	5.23	3.99	2.62	5.26	3.00	6.72
Percentage of total crop uninjured for storage by codling moth	84.23	81.34	86.39	80.54	82.51	83.86	78.43	78.02	82.93	80.01	88.06	81.71

abundant, but where very few trees of the same variety were available for the work. While the results showed decided average benefits from the spraying, it was thought best to supplement this work by a test conducted on a larger scale in one of the more distinctively apple-producing regions of the state, and to include the use of a larger number of different mixtures. Accordingly, in June, 1906, arrangements were made for carrying on such a test in the orchard of W. H. Perkins, near Quincy, Adams Co. A block of Ben Davis trees, fourteen years old, was selected, and divided into twelve plats. Each plat consisted of three rows of five trees each, so that a plat contained fifteen trees, except in cases where one or two trees were

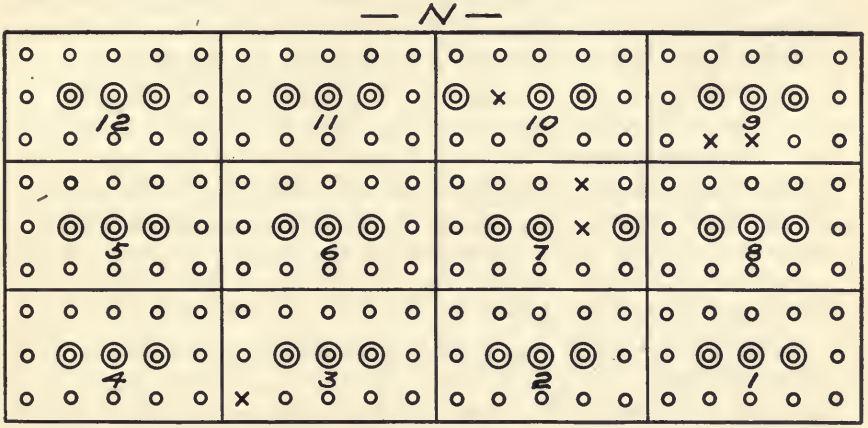

DIAGRAM OF EXPERIMENTAL BLOCK AT QUINCY, 1906.

missing. The trees had been sprayed twice in the spring, and were carrying a fair crop of fruit. In the late spraying the various plats were treated as follows:

1. Paris green ¼ lb., lime 4 lb., water 50 gal. Five applications.
2. Paris green ¼ lb., lime 4 lb., copper sulphate 4 lb., water 50 gal. Five applications.
3. Arsenate of lead (double strength) made from lead acetate 25 oz., soda arsenate 10 oz., water 50 gal. Five applications.
4. Check—no late spraying.
5. Commercial arsenate of lead 2 lb., water 50 gal. Five applications.
6. Commercial arsenate of lead 1 lb., Paris green ¼ lb., lime 4 lb., water 50 gal. Five applications.
7. Commercial arsenate of lead 2 lb., lime 4 lb., copper sulphate 2 lb., water 50 gal. Five applications.
8. Check—no late spraying.

9. Paris green ¼ lb., lime 4 lb., copper sulphate 2 lb., water 50 gal. Five applications.
10. Paris green ¼ lb., lime 4 lb., copper sulphate 2 lb., water 50 gal. Three applications.
11. Commercial arsenate of lead 2 lb., lime 4 lb., copper sulphate 2 lb., water 50 gal. Three applications.
12. Check—no late spraying.

The plats receiving five applications were sprayed July 10 or 11, 20, August 1, 17, and 29, while those receiving three applications were sprayed July 11, 20, and August 1. The entire plat was sprayed in each case, but records were kept regarding the product of only three trees in each plat. Except where vacancies occurred rendering such selection impossible, these trees were in the middle of the plat. The accompanying diagram shows the arrangement of the plats and the location of the trees selected for the records.

July 19 and 20 all windfalls were gathered from under the selected trees, and a complete record was kept of all apples which fell from these trees after that time, as well as of all hand-picked fruit gathered at the harvest, October 5 to 10. Both windfalls and hand-picked fruits were sorted on the basis of codling moth injuries, though no records were kept regarding the point of entrance of the worms nor the brood to which the various worms belonged. The results are given in Table 37.

These figures show that in general the attack of the codling moth was not severe, and that it varied in severity in different plats under the same treatment. The three check plats showed wider differences among themselves than any of the various sprayed plats. When the highest percentage of injury to the total crop in a check plat is only 8.57, and the difference betwen two check plats is 4.58, it is impossible for the results of spraying to appear very marked, or for any definite conclusions to be drawn regarding the relative efficiency of various mixtures. When so small a percentage of the fruit is attacked, spraying for the second brood of the codling moth would not be attended with financial profit.

WORK AT GRIGGSVILLE

In addition to the test conducted in the commercial orchard near Quincy in 1906, a few trees in the orchard of John Sawdon, near Griggsville, Pike Co., were sprayed with special reference to the second brood of the codling moth, and detailed records kept regarding the extent of codling moth injuries to the product. Six trees were selected which had been sprayed with Bordeaux mixture and

Paris green, April 25, May 14, and 21, for the scab and first brood of codling moth, the last two applications being made after the petals had fallen. Four other trees were selected which had received no early applications. These trees were divided into five lots of two trees each. Three of these lots were sprayed five times for the second brood of the codling moth, the dates of application being July 14, 21, August 2, 15, and 30. The full treatment of the various lots for the entire season was as follows:

1. Three early applications of Bordeaux and Paris green: five late applications of Paris green, ¼ lb. to 50 gal., with dilute Bordeaux mixture.
2. Three early applications of Bordeaux and Paris green; five late applications of commercial arsenate of lead, 2 lb. to 50 gal.
3. Three early applications of Bordeaux and Paris green. No later treatment.
4. No early spraying. Five late applications of Paris green, ¼ lb. to 50 gal., with dilute Bordeaux mixture.
5. Check—no spraying whatever.

The ground under the trees was cleared of all windfalls July 14 and 16, and complete records were kept regarding all apples falling after this preliminary clearing. Table 38 gives the results of the examination of these windfalls in reference to codling moth injuries.

TABLE 38.—EXAMINATION OF WINDFALLS, GRIGGSVILLE, 1906

	No. 1.	No. 2.	No. 3.	No. 4	No. 5.
Sound	284	305	205	273	39
Injured by first brood codling moth:					
Entering at calyx	189	106	177	392	387
Entering at stem	11	1	10	6	9
Entering at side	42	33	45	57	42
Total injured by first brood codling moth	242	140	232	455	438
Injured by second brood codling moth:					
Entering at calyx	311	251	343	468	449
Entering at stem	25	12	43	22	28
Entering at side	65	47	117	65	128
Total injured by second brood codling moth	401	310	503	555	605
Otherwise injured	739	467	707	721	2135
Total number of windfalls	1666	1222	1647	2004	3217
Percentage of windfalls which were sound.	17.04	24.95	12.44	13.12	1.22
Percentage of windfalls injured by first brood codling moth	14.52	11.45	14.08	22.25	13.61
Percentage of the windfalls injured by first brood codling moth, in which the worm entered at the calyx	78.09	75.71	76.29	86.15	88.35
Percentage of windfalls injured by second brood codling moth	24.07	25.36	30.54	22.70	18.80
Percentage of the windfalls injured by second brood codling moth, in which the worm entered at the calyx	77.55	80.96	68.19	84.32	74.21

Eight of the trees in this experiment carried so much fruit that thinning became necessary in order to prevent breaking of the limbs. This thinning was done September 3 and 4. The apples were removed without selection, but were all examined later in reference to codling moth injuries, and the results recorded. It is impossible to determine how much of this fruit would have fallen had it not been thinned, and therefore impossible to determine which treatment would have resulted in the retaining of the highest percentage of the total crop on the trees until the final harvest, had thinning been unnecessary.

The hand-picked fruit was gathered October 19 to 22, and sorted on the basis of codling moth injuries. All specimens showing indications of the work of the codling moth were cut open to determine the extent of the injury. The record of this examination is given in the following tables.

TABLE 39.—EXAMINATION OF HAND-PICKED FRUIT FROM TREES SPRAYED FOR CODLING MOTH, GRIGGSVILLE, 1906

	No. 1	No. 2	No. 3	No. 4	No. 5
Total number of apples	3695	3546	4452	3881	2999
Visibly attacked by second brood codling moth at calyx:					
Injured for storage	152	71	77	226	88
Worm found in apple	40	17	16	29	7
Worm gone to interior but not found:					
Fruit badly damaged	72	48	59	163	70
Fruit not badly damaged	40	6	2	34	11
Uninjured for storage (worm stopped near surface)	20	20	6	20	4
Visibly attacked by second brood codling moth at stem:					
Injured for storage	15	0	13	10	12
Worm found in apple	5	0	3	6	0
Worm gone to interior but not found:					
Fruit badly damaged	9	0	8	4	11
Fruit not badly damaged	1	0	2	0	1
Uninjured for storage (worm stopped near surface)	5	1	4	2	0
Visibly attacked by second brood codling moth at side:					
Injured for storage	105	26	78	57	32
Worm found in apple	19	6	11	6	6
Worm gone to interior but not found:					
Fruit badly damaged	55	19	63	50	24
Fruit not badly damaged	31	1	4	1	2
Uninjured for storage (worm stopped near surface)	52	22	29	24	23
Injured by first brood codling moth					
Entering at calyx	76	6	4	12	3
Entering at stem	1	0	0	0	0
Entering at side	35	2	2	2	1
Not visibly attacked by codling moth	3234	3398	4239	3528	2836

TABLE 40.—SUMMARY OF EXAMINATION OF HAND-PICKED FRUIT FROM TREES SPRAYED FOR CODLING MOTH, GRIGGSVILLE, 1906

	No. 1	No. 2	No. 3	No. 4	No. 5
Total number of apples	3695	3546	4452	3881	2999
Visibly attacked by second brood codling moth	349	140	207	339	159
Injured for storage by second brood codling moth	272	97	168	293	132
Worm found in apple	64	23	30	41	13
Worm gone to interior but not found:					
Fruit badly damaged	136	67	130	217	105
Fruit not badly damaged	72	7	8	35	14
Uninjured for storage (worm stopped near surface)	77	43	39	46	27
Injured by first brood of codling moth	112	8	6	14	4
Not visibly attacked by codling moth	3234	3398	4239	3528	2836

TABLE 41.—PERCENTAGE OF HAND-PICKED FRUIT INJURED BY CODLING MOTH, GRIGGSVILLE, 1906

	No. 1	No. 2	No. 3	No. 4	No. 5
Percentage visibly attacked by second brood codling moth	9.44	3.94	4.64	8.73	5.30
Percentage injured for storage by second brood codling moth	7.36	2.73	3.77	7.55	4.40
Percentage in which second brood worms stopped near surface	2.08	1.21	.87	1.18	.90
Percentage injured by first brood only	3.03	.22	.13	.36	.13
Percentage uninjured for storage by codling moth (both broods)	89.61	97.05	96.10	92.09	95.47
Percentage of apples attacked by second brood in which worms stopped near surface	22.06	30.71	18.84	13.56	16.98
Percentage of the apples injured for storage by second brood codling moth, which were entered at calyx	55.88	73.19	45.83	77.13	66.66

It will be seen that the percentage of hand-picked fruit injured by the codling moth was in every case comparatively small. The highest percentage of injury was in lot No. 1, which received both early and late applications. The trees in this lot were not as thoroughly sprayed in 1904 as were those in the other lots, and were badly infested that year. None of the trees in the orchard were sprayed in 1905. It seems probable that the trees in lot No. 1 were more severely attacked in 1906 than were those in the other lots. They must certainly have been more severely attacked than the check trees, for in spite of the spraying they showed a higher percentage of injury.

On account of the necessity of thinning the fruit, it is impossible to compare the results of the various treatments on the basis of

"percentage of total crop remaining on trees uninjured till the harvest." Under these circumstances it is probable that the fairest way to compare the results of the different treatments is on the basis of the percentage of the total crop (including windfalls, thinned and hand-picked fruit) injured by the codling moth. The data for determining these percentages and the percentages themselves are given in Table 42.

TABLE 42.—EXAMINATION OF TOTAL CROP FROM TREES SPRAYED FOR CODLING MOTH, GRIGGSVILLE, 1906

	No. 1	No. 2.	No. 3.	No. 4.	No. 5.
Windfalls	1666	1222	1647	2004	3217
Thinned fruit	1507	1368	2575	1950	1556
Hand-picked (mature fruit)	3695	3546	4452	3881	2999
Total crop	6868	6136	8674	7835	7772
Injured by first brood codling moth:					
Entering at calyx	371	135	231	489	414
Entering at stem	16	1	13	7	9
Entering at side	97	43	73	70	55
Total injured by first brood codling moth	484	179	317	566	478
Injured by second brood codling moth:					
Entering at calyx	596	392	618	879	687
Entering at stem	49	18	90	42	64
Entering at side	221	110	264	161	210
Total injured by second brood codling moth	866	520	972	1082	961
Not visibly attacked by codling moth	5518	5437	7385	6187	6333
Percentage of total crop injured by first brood codling moth	7.04	2.91	3.65	7.22	6.17
Percentage of total crop injured by second brood codling moth	12.61	8.47	11.20	13.81	12.36
Percentage of total crop injured by codling moth (both broods)	19.65	11.38	14.85	21 03	18.53
Percentage of the apples injured by first brood codling moth, in which the worm entered at the calyx	76.65	75.42	72.87	86.39	86.61
Percentage of the apples injured by second brood codling moth, in which the worm entered at the calyx	68.82	75.38	63.58	81.23	71.48

The smallest percentage of injured fruit was from lot No. 2, which, in addition to the early spraying, received five late applications of arsenate of lead. Lot No. 3, which received only the early applications, showed only slightly more injury than this lot. Lot No. 4, which received only the late applications and lot No. 1, which was sprayed both early and late, showed more injury than the un-

sprayed lot (No. 5.) Under the conditions existing in this orchard in 1906, when the general attack of the codling moth was comparatively slight, none of the spraying for the second brood gave results which would warrant the expense of the operation.

It is worthy of notice that a very large percentage of the apples injured by the second brood of the codling moth were entered at the calyx. The records of the previous experiments show that a similar condition existed at Urbana in 1903, and that the results of the late spraying were that year much less favorable than in years when a smaller proportion of the injured apples were entered at the calyx. The records for four years show wide variations in the percentage of the apples injured by the second brood of the codling moth which were entered at the calyx end. Records on this point for the four years were kept in regard to the windfalls only. Considering all the apples which fell after about July 15 (the date varying in different years) from the trees under observation which had received the usual early spraying but no late spraying, the percentages of the fruits injured by second brood codling moth larvæ in which the worm had entered at the calyx, were, for the different years, as follows:

TABLE 43.—PERCENTAGE OF INJURED FRUITS ENTERED AT CALYX

Year.	1902.	1903.	1904.	1906.
Number of injured specimens	510	479	512	503
Percentage entered at calyx	44.90	73.07	47.65	68.19

This indicates that the habits of the second brood larvæ may be different in different years, and that the poorer results of the late spraying in 1903 and 1906 as compared with 1902 and 1904 may have been due partly to this difference in the habits of the worms.

CONCLUSIONS

1. Spraying for the first brood of the codling moth may be commenced as soon as most of the petals have fallen from the trees, and the first application should be completed within seven days from that time.

2. The method employed in this first application should be one which will result in the lodging of considerable spraying material within the calyx cavities of the highest possible percentage of the young apples. A comparatively large amount of material applied

under high pressure through fine nozzles is most likely to secure the desired end, though if the amount is excessive, russeting of the fruit and injury to the foliage may follow.

3. While one thorough application at the proper time will result in the saving of a large percentage of the fruit that would otherwise be injured by the first brood of the codling moth, it is probable that at least one additional application for the first brood should be made, and the investigations in 1902 indicate that one or two further applications may result in the saving of still more fruit.

4. It is possible to kill many of the second brood larvæ of the codling moth by means of a poisonous spray applied late in the season.

5. The habits of the second brood larvæ of the codling moth vary greatly in reference to the point of entrance into the apple.

6. Late spraying for the second brood of the codling moth is more effective against the worms which attack the apples at the side than against those which seek entrance at the calyx. Therefore, when a large proportion of the second brood larvæ enter the apples by way of the calyx, the late spraying is less effective in saving the crop than is the case when a larger proportion of the larvæ attack the apples at the side.

7. The thoroughness of the early applications of spraying material for the first brood of the codling moth may have a marked influence upon the control of those larvæ of the second brood which seek entrance at the calyx.

8. If the late spraying is not commenced until after the first worms of the second brood have entered the apples, but an application is made before these worms penetrate deeply into the fruit, many of the worms which have entered the sides of the apples may be killed by the spray applied after they have entered.

9. Since new larvæ of the second brood may continue to appear for a period of four or five weeks, repeated applications of spraying material are necessary, and there will usually be some larvæ which have not been destroyed by previous applications, but which are feeding just beneath the surface of the fruit at the time an application is made. There may therefore be many apples at the harvest which have been attacked by the codling moth, and slightly blemished before the worms were killed.

10. Apples in which codling moth larvæ have been killed close to the surface are but slightly blemished, and keep in cold storage almost as well as do specimens absolutely without blemish.

11. The use of a simple mixture of Paris green and water is not to be recommended for the late spraying of apple trees, because there is danger of injury to the foliage and excessive dropping of the fruit by reason of injury to the stems.

12. Even when used with lime, Paris green, especially if used in quantities greater than ¼ lb. to 50 gallons, is likely to cause excessive dropping of the fruit. However, when used in combination with Bordeaux mixture, the Paris green does not have this undesirable effect.

13. Paris green used in combination with Bordeaux mixture, at the rate of ¼ lb. to 50 gallons, and arsenate of lead made from 25 oz. of lead acetate and 10 oz. of soda arsenate to 50 gallons, are about equally efficient in late spraying for the control of the second brood of the codling moth.

14. Late spraying for the second brood of the codling moth is much more effective some years than others.

15. When the attack of the second brood of the codling moth is not severe, late spraying for the control of this brood will not result in sufficient benefit to pay for the expense of the operation. If, however, an orchard is to be sprayed with Bordeaux mixture late in the season for the control of fungous diseases, it will be advisable to add Paris green to the mixture for the sake of its effect upon the second brood of the codling moth.